

## Cosmic Times: 1919

1

*Cosmic Times* is a series of six posters with classroom lessons which trace the development of our understanding of the nature of the universe during the past century.

In this first edition of *Cosmic Times*, several concepts are introduced which will be revisited and built upon in future editions. The first concept is the idea of Einstein’s General Relativity and its first confirmation. In addition, the idea of the size of the Universe is introduced. In 1919, the Universe was viewed to contain only the stars in the Milky Way. Other galaxies had not yet been resolved into their constituent stars, so it was not apparent that some of the fuzzy nebula were, indeed, outside our own galaxy. The Universe was a much smaller place than it is today, but change was just on the horizon.

The language in the 1919 *Cosmic Times* mimics the style of writing that would have appeared in a real 1919 newspaper. The poster also mimics the layout of newspapers of the time. We have, however, taken some creative license to make it more readable in a classroom setting. Real newspapers of the time would have had 5-7 narrow columns. The size of the text in each column would have gotten smaller and smaller as you read down the column, so the more details you wanted, the harder you would have had to work to read it.

The *Cosmic Times* website, <http://cosmictimes.gsfc.nasa.gov/> provides a complete teacher guide for this poster and the accompanying lessons. There you can also find two newsletter versions of the poster: one of the newsletters contains the same text as the poster, while the other is a modern-language translation for a slightly lower reading level. We provide here a summary of the articles, a synopsis of the lessons, and one of the lessons.

## Two Versions of Gravity: Newton and Einstein

4

Suggested Grade Level(s) 11-12  
Estimated class time 2 45-minute periods

### Summary

Students will present information to their peers about both Newton’s Law of Gravitation and Einstein’s General Theory of Relativity. Students will need to have either studied both Newton’s Law of Gravitation and Einstein’s Theory of Relativity or be given the time and resources to look up this information. The lesson plan below assumes that they have been taught both, but it could easily be modified to incorporate an independent research approach to covering Einstein’s theory.

### Objectives

- Students will be able to compare and describe the key differences between Einstein’s Theory of General Relativity and Newton’s Theory of Universal Gravitation.
- Students will be able to organize and be able to orally describe an idea or concept.
- Students will be able to construct and analyze a scientific argument.
- Students will be able to describe science as a process and define the key components that make a theory valid.
- Students will be to describe the importance of new data as the determining factors as to if a scientific theory is valid and accurate.
- Students will be able to display analytical and critical questioning skills.

### National Science Education Content Standards

- NS.9-12.2 NS.9-12.1 SCIENCE AS INQUIRY
- NS9-12.2 PHYSICAL SCIENCE
  - Motions and forces
- NS.9-12.7 HISTORY AND NATURE OF SCIENCE -
  - Science as a human endeavor
  - Nature of scientific knowledge
  - Historical perspectives

to discover Neptune. Obviously, no planet was ever found but this clearly illustrates the confidence in Newtonian Physics at that time.

7

- Each group will be responsible for developing 5 components (introduction, history, theoretical description, testing the theory and closing argument) to justify the validity of their chosen theory.
- The ideal size for each sub- group is 2-3 students.
  - Sub-group 1 will create an introduction for their theory. They will introduce the claims to be made by their group.
  - Sub-group 2 will create the argument concerning the history of the formulation of the theory. The argument must explain the historical context of how the theory came to be written. The argument must explain what evidence and experiments went into the theories formulation.

**Teacher Note:** Both groups for the historical content should relate how their theories came to be founded. This does not include how the theory directly relates to planetary motion but rather how both Newton and Einstein formulated their ideas.

- Sub-group 3 will create the argument addressing the theoretical description of the theory. They must explain to the class how the theory relates to the data gathered about planetary movements of the planets.

**Teacher Note:** In this section the students explain how each theory address planetary motion. The Newton group should include the leap made by Newton that falling objects and planets are subject to the same forces. Einstein’s group should include discussion of mass as a Space-Time warping agent. The Newton group can also include information about the success of Newtonian ideas with regard to planetary discovery while the Einstein group can point out the problem of mercury.

- Sub-group 4 will create the argument that focuses on how the theory can be tested with regard to the 1919 eclipse. They must describe how their theory relates to the upcoming eclipse of 1919 and why they believe that their theory will yield the actual result.

**Teacher Note:** If using a pre 1919 format, it should be made clear to the students that no results have been obtained at this point. They are just making a case for how the upcoming 1919 eclipse data will yield final solution to the

## Summary of the Articles

(for more information, see  
[http://cosmictimes.gsfc.nasa.gov/1919/guide/teachers\\_guide.html](http://cosmictimes.gsfc.nasa.gov/1919/guide/teachers_guide.html))

### Sun’s Gravity Bends Starlight

This article discusses the first confirmation of Einstein’s Theory of General Relativity. He had introduced the theory several years earlier (1915); however, since General Relativity reduces to Newtonian Gravity except in cases of extreme speeds (i.e. close to the speed of light) or in strong gravity, the tests of General Relativity were somewhat limited.

### Sidebar: Why a Total Eclipse?

In day-to-day life, Newtonian gravity is enough to predict how objects will behave. In order to see the effects of General Relativity, extraordinary conditions are needed – either high speeds, close to the speed of light, or strong gravity. In the early 1900s, the most accessible test for General Relativity was to watch the behavior of starlight as it passes very near the Sun.

### Mount Wilson Astronomer Estimates Milky Way Ten Times Bigger Than Thought

In 1919, astronomers did not realize that there were galaxies in the Universe besides our own Milky Way. That discovery did not happen until 1924. At the time, they thought that the Universe was populated uniformly by stars and nebulae. Astronomers had observed nebulae, some of which appeared spiral, but they could not resolve these nebula into stars. There was a debate going on at the time of this issue of the *Cosmic Times*, as to whether these nebula were indeed just gas and dust or if they were comprised of stars. The telescopes of the time were not sensitive enough to settle the question.

### Expanding or Contracting?

When applied to the real Universe, the equations of General Relativity predict that the Universe cannot be static – it must be either expanding or contracting. While an expanding Universe is an accepted concept today, it was a radical idea in 1919. Certainly they knew that the heavens were not unchanging, but it was largely believed that the Universe, as a whole, was static.

### In Their Own Words

This column includes excerpts from various papers which introduce concepts that will be built upon in future issues of the *Cosmic Times*. The quotes may be a little difficult to understand, as they are taken directly from published papers by the listed authors.

### Knowledge Prerequisite

- Newton’s Theory of Universal Gravitation
- The fundamental concepts of Einstein’s theory of General Relativity. A mathematical understanding is not necessary
- General knowledge of planetary motion.
- An understanding of how both Einstein’s and Newton’s theories apply to the 1919 solar eclipse

### Teacher Background

The goal of this lesson is to create two groups of students with the purpose of exchanging information about how two different theories explain a natural phenomenon and to illustrate how the scientific process allows a new, more complete theory to take the place of an older theory that does not produce accurate results for a new discovery. This can be done several ways. Some suggestions are poster presentations, Pod casts, debates, or PowerPoint. The main objective is for each group to become an expert of the material for their topic and then present that material to their peers for discussion. Regardless of how you choose for the information to be presented, the key objectives are:

- Students will be able to research and formulate arguments using both General Relativity and Newtonian Mechanics to explain a phenomena
- Students will be able to describe science as a process and demonstrate the role of data as the guiding force in what is accepted a scientific theory.

It is left open to you whether you want to impose a limitation of using only data available prior to the 1919 eclipse in their project. If you choose to use this limitation, it does make a clear example of how data provides the ultimate answer as to which theory is more complete. Through out the lesson the Teacher Note for your benefit, which you may give to the students, as you deem necessary, to facilitate the flow of the lesson.

### Materials

- Books including that include descriptions of Einstein’s theory of General Relativity and Newtonian Physics
- Access to research material so that students can do additional research for their arguments

debate. If not, this group should include references to success by Einstein’s theory regardless of time period. It should also be noted here that the bending of light as explained by Newton has to do with the momentum of the light and it because of this momentum that light “feels” gravity.

- Sub-group 5 will create a closing statement for their group. They will summarize the ideas put forth and come up with a strong ending statement

**Teacher Note:** Both Introduction and Conclusion groups should make sure they communicate with the other sub-groups about what is to be presented so that strong opening and closing presentations can be made that demonstrate the usefulness of their groups’ theory.

### III. Explanation: Students are now involved in an analysis of their exploration. Their understanding is clarified and modified because of reflective activities

- Each group must prepare a statement describing what they are going to cover for their argument. The statement should take about 3-5 minutes. They then must be prepared to answer any questions issued by the other side about what they talked about with there argument. Each argument should be supported by ideas from their theory. Because of this questioning opportunity, both sides should be familiar with both theories to a degree.

**Closure:** Have the students share with other members of their group what they learned about their piece of the presentation through the creation of their piece.

### Day 2 Presentation

Have the students review what they did the day before. Then set the students up for the presentation.

**Teacher Note:** The actual presentation of information depends on how you decided for the students to present their information. Either one group can go completely followed by the other or you can do a back and forth method. What follows below is an example of a back and forth method.

## Summary of 1919 Cosmic Times Lessons

3

Each of the lessons uses elements of the 5E model of Engage, Explore, Explain, Elaborate, and Evaluate. These lessons may be downloaded from <http://cosmictimes.gsfc.nasa.gov/1919/1919.html> -

### Einstein and His Times (grades 7-12) -

In this multidisciplinary lesson, students look at other 1919 events to decide if Einstein should be elected “Man of the Year” -

### Eclipses and Moon Phases (grades 7-8) -

Students explore how eclipses happen and why Einstein needed a total eclipse to image stars near the Sun. -

### Two Versions of Gravity: Newton and Einstein (grades 11-12) -

Students explore the differences between Einstein and Newtonian gravity through an information exchange. This lesson is given in its entirety here on the back of the poster.

### Einstein’s Gravity (grades 9-12) -

Students use hands-on a demonstration to understand how General Relativity explains gravity. Students also explore Einstein’s theories through outside research. -

### Procedure

#### Day 1 Prep

##### I. Engagement

Have the students think about the differences between Einstein’s theory of General Relativity and Newton’s theory of Universal Gravitation. Have them share their ideas with a neighbor.

##### II. Exploration: in this section students are given time to think, plan, investigate, and organize collected information

- Organize the students so that they form two groups or teams. Group One will represent Einstein’s Theory and Group Two will represent Newton’s Theory. Each group is then comprised of 5 smaller sub-groups.

**Teacher Note:** Be sure that students at this point realize that they will be researching information to present to their peers. It is at this point that you must decide whether to limit them to only information that was available previous to 1919 or not. If you do, the data about the eclipse is not available and Newtonian mechanics has a strong accepted footing from the data acquired to that point. It is the task of the Newtonian physics groups to work under this old guard mentality while the General Relativity groups should demonstrate that their theory works as well, and should point out the holes in the Newtonian picture.

- The main question for the project is whether Newton’s Theory of Gravitation or Einstein’s Theory of Relativity is responsible for the movement of the planets. The students will be making a case for why each theory is valid.

**Teacher Note:** If used as a pre-1919 project, it should be clear to the students that Newtonian mechanics has had recent success with the discovery of Neptune due to gravitational perturbations. In fact all planetary motion as of the early 1900’s had indeed been shown to follow the Newtonian model, the only exception to this rule being the precessions of the planet Mercury. It should be noted that General Relativity did correctly predict the precession and that this knowledge was known at the time. However several ad-hoc fixes were attempted to counter this notion such as the belief of dust particles between mercury and even the belief that a planet nicknamed Vulcan were responsible for the discrepancy between data and theory. A search was actually conducted for the planet Vulcan at the time using the same technique that was used

- Split the room in half with the groups on either side.
  - Newton’s group will present their opening presentation.
  - Einstein’s group will present their opening presentation.
- Each group will then take turns presenting their information.
  - They will alternate presentations of their work for Newton or Einstein for each sub-group.
  - During the presentation, the other group should develop questions to ask the presenting group. After each presentation, the other group should ask their questions.
    - The questions should either be a clarification of what they presented, i.e. did they explain it correctly?
    - They should ask questions regarding validity of the ideas addressing the orbit of the planet.
- The presentation will then finish with the closing statements.
- At the conclusion of the presentations, the students will write a 1-page summary describing the ideas presented by each theory during the debate and how the ideas relate to the upcoming eclipse (**If done using a pre-1919 format. You could also do just a comparison of the theories here.**)

**Teacher Note:** At the conclusion of the presentations, the idea that science is a process and that the 1919 eclipse yields the data necessary to prove which theory is valid should be reinforced. The main objective of the activity is to develop the idea that the process of science is reinforced through the debates of various theories. Yet in the end, it is the data and observations that yield the actual accepted theory hence as data improves, theories change. The idea that the story is never over should be made clear and that from 1919 onward to today, the ideas behind how our world behaves have changed and as we move into the future they will continue to do so. It is at this point that the idea that the 1919 debate data proves Einstein right should be made clear to the students.

**Closure:** To bring closure to the presentation activity, students should share what they learned about the scientific process and the theories as a result of the debate activity.

9

8